Tunable white light generating nanocyrstal-hybridized LEDs

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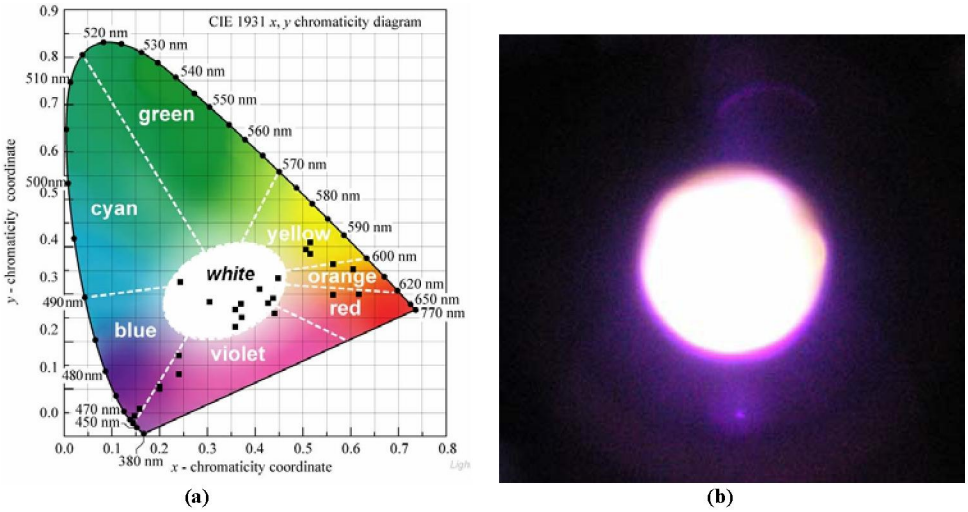
Abstract: We hybridize CdSe/ZnS core-shell nanocrystals on InGaN/GaN near-UV/blue LEDs to generate light widely tunable across the visible spectral range and within the white region of the chromaticity diagram with adjustable tristimulus coordinates. We present the design, growth, fabrication, and characterization of these nanocrystal-hybridized LEDs.

OCIS codes: (160.2540) Fluorescent and luminescent materials; (230.3670) Light-emitting diodes

To date white light-emitting diodes (WLEDs) have been implemented using different approaches including multi-chip WLEDs, multi-layer monolithic WLEDs, and color-conversion WLEDs, for example, using phosphor molecules coated on blue-emitting nitride LEDs. Among them, the color-conversion technique has been the most successful. However, the phosphors available for use in these devices present difficulties in controlling granule size and depositing films uniformly, which lead to undesired visible color variations [1]. Furthermore, phosphor photoemission properties are not easy to tune controllably. As an alternative to phosphor, we exploit nanocrystals (NCs) for use in color conversion to generate white light. To date we have introduced white light generation using CdSe/ZnS core-shell nanocrystals of single, dual, trio, and quadruple combinations hybridized with blue and near-UV InGaN/GaN based LEDs. [2-4]. Also, a blue/green two-wavelength InGaN/GaN LED coated with a single type of red NC and a blue InGaN/GaN LED with a single type of yellow NC and a dual type of red and green NCs have been demonstrated [5-7].

In this conference, we present the hybridization of CdSe/ZnS nanocrystals on InGaN/GaN LEDs to generate light that is widely tunable across the visible spectral range as shown in Fig. 1(a). Here we report the design, growth, fabrication, and characterization of these hybrid NC-LEDs. Fig. 1(b) shows an exemplary implementation of white light generation with such a nanocrystal-hybridized LED.



(a) (b)

Figure 1. (a) (x, y) tristimulus coordinates of our nanocrystal-hybridized LEDs on the C.I.E. (1931) chromaticity diagram and (b) photograph of white light generation from one of such hybrid NC-LEDs.

We grow and fabricate n-UV and blue InGaN/GaN LEDs shown in Fig. 3 (a) and (c), respectively. Our n-UV LED has a peak electroluminescence at 383 nm and our blue LED, at 452 nm, as shown in Fig. 3 (b) and (d) at different current injection levels at room temperature. We use 2-3 nm thick InGaN/GaN quantum well for the n-UV LED and 4-5 nm think well for the blue LED. We use four types of CdSe/ZnS core-shell NCs shown in Fig. 3 (a)-(d) with their photoluminescence in the visible spectral range of cyan, green, yellow, and red and with their corresponding diameters ranging from 1.9 nm to 5.2 nm. Our NCs exhibit photoluminescence peaks at 500 nm, 540 nm, 580 nm, and 620 nm, respectively, as characterized in Fig. 4 (e). Using different combinations of these nanocrystals hybridized on these LEDs, we conveniently obtain visible light generation widely tunable across the color diagram as demonstrated in Fig. 1(a).

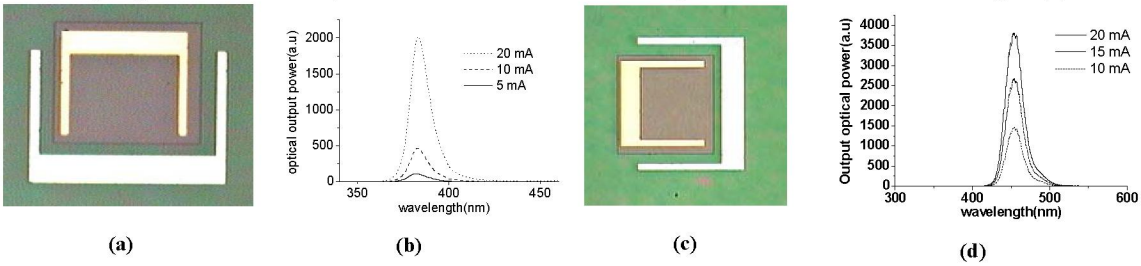


Figure 2. (a) micrograph of our near-UV InGaN/GaN LED and (b) its electroluminescence spectrum, and (c) micrograph of our blue InGaN/GaN LED and (d) its electroluminescence spectrum.

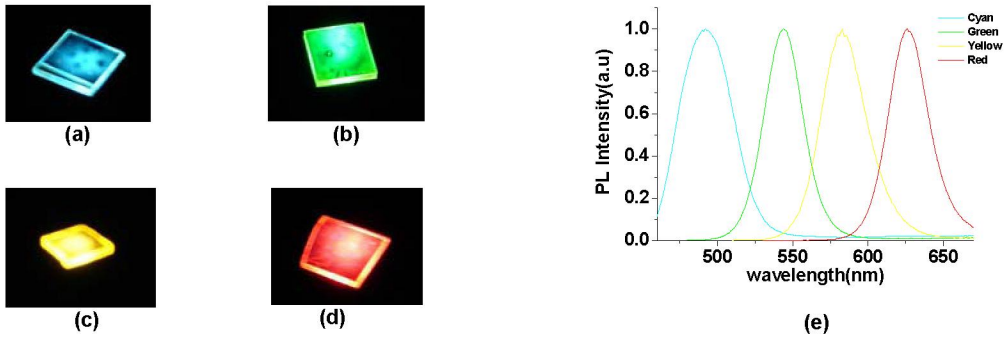


Figure. 3. Photoluminescence photographs of (a) cyan NC film, (b) green NC film, (c) yellow NC film, (d) red NC film, and (e) their corresponding photoluminescence spectra.

In conclusion, we hybridize cyan, green, yellow, and red CdSe/ZnS core-shell nanocrystals on InGaN/GaN based blue/near-UV LED to generate light widely tunable across the visible spectral range and within the white region of the chromaticity diagram with adjustable tristimulus coordinates. These hybrid light sources hold promise for future lighting and display applications with their widely tunable color properties.

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